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Sir Charles

FUEL.

BY

C. WILLIAM SIEMENS, D.C.L., F.R.S.

TO WHICH IS APPENDED THE

VALUE OF ARTIFICIAL FUELS

AS

COMPARED WITH COAL

BY

JOHN WORMALD, C. E.

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ON FUEL.

In accepting the invitation of the Council of the British Association to deliver an address to the operative classes of this great industrial district, I felt that I was undertaking no easy task. Having to speak on behalf of the Association, and in the presence of many of its most distinguished members, I am bound to treat my subject scientifically; but I have to bear in mind at the same time that I am addressing myself to men unquestionably of good intelligence, but without that scientific training which has almost created a language of its own.

It is no consolation for me to think that those who have taken a similar task upon themselves in former years, have admirably succeeded in divesting highly scientific subjects of the formalism in which they are habitually clothed. The very names of these men—Tyndall, Huxley, Miller, Lubbock, and Spottiswoode—are such as to preclude in me all idea of rivalry, but I hope to profit by their example, and to remember that truth must always be simple, and that it is only where knowledge is imperfect that scientific formulæ must take the place of plain statements.

The subject matter of my discourse is "Fuel;" a matter with which every one of us has become familiarized from his infancy, but which nevertheless is but little understood even by those who are most largely interested in its applications; it involves considerations of the highest *à priori* interest, both from a scientific and a practical point of view.

I purpose to arrange my subject under five pricipal heads:—

1. What is fuel?
2. Whence is fuel derived?
3. How should fuel be used?
4. The coal question of the day?
5. Wherein consists the fuel of the sun?

WHAT IS FUEL?

Some of you may have already said within yourselves that it is but wasted time to enlarge upon such a theme, since all know that fuel is coal drawn from the earth, from deposits, with which this country especially has been bountifully supplied; why disturb our plain understanding by scientific definitions which will neither reduce the cost of coal, nor make it last longer on our domestic hearth?

Yet I must claim your patience for a little, lest, if we do not first agree upon the essential nature of fuel, we may afterwards be at variance in discussing its origin and its uses, the latter at any rate being of practical interest, and a subject worthy of your most attentive consideration.

Fuel, then, in the ordinary acceptation of the term, is carbonaceous matter, which may be in the solid, the liquid, or in the gaseous condition, and which, in combining with oxygen, gives rise to the phenomenon of heat. Commonly speaking, this development of heat is accompanied by flame, because the substance produced in combustion is gaseous. In burning coal, for instance, on a fire-grate, the oxygen of the atmosphere enters into combination with the solid carbon of the coal and produces carbonic acid, a gas which enters the atmosphere, of which it forms a necessary constituent, since without it, the growth of trees and other plants would be impossible. But combustion is not necessarily accompanied by flame, or even by a display of intense heat. The metal magnesium burns with a great display of light and heat, but without flame, because the product of combustion is not a gas but a solid, viz., oxide of magnesium. Again, metallic iron, if in a finely divided state, ignites when exposed to the atmosphere, giving rise to the phenomena of heat and light without flame, because the result of combustion is iron oxide or rust; but the same iron, if presented to the atmosphere—more especially to a damp atmosphere—in a solid condition, does not ignite, but is nevertheless gradually converted into metallic oxide or rust as before.

Here, then, we have combination without

the phenomena either of flame or light; but by careful experiment we should find that heat is nevertheless produced, and that the amount of heat so produced precisely equals that obtained more rapidly in exposing pulverulent iron to the action of oxygen. Only, in the latter case the heat is developed by slow degrees, and is dispersed as soon as produced, whereas in the former the rate of production exceeds the rate of dispersion, and heat, therefore, accumulates to the extent of raising the mass to redness. It is evident from these experiments that we have to widen our conception, and call fuel "any substance which is capable of entering into combination with another substance, and in so doing gives rise to the phenomenon of heat."

In thus defining fuel, it might appear at first sight that we should find upon our earth a great variety, and an inexhaustible supply of substances that might be ranged under this head; but a closer investigation will soon reveal the fact, that its supply is, comparatively speaking, extremely limited.

In looking at the solid crust of the earth, we find it to be composed for the most part of siliceous, calcareous, and magneceous rock; the former, silica, consisting of the metal silicon combined with oxygen, is not fuel, but rather a burnt substance which has parted with its heat of combustion ages ago; the second, limestone, being carbonate of lime, or the combination of two substances, viz., calcic oxide and carbonic acid, both of which are essentially products of combustion, the one of the metal calcium, and the other of carbon; and the third, magnesia, a combination of oxygen with the metal magnesium (which I have just burnt before you), and which, further combined with lime, constitutes dolomite rock, of which the Alps are mainly composed. All the commoner metals, such as iron, zinc, tin, aluminium, sodium, etc., we find in nature in an oxidized or burnt condition; and the only metallic substances that have resisted the intense oxidizing action that must have prevailed at one period of the earth's creation are the so-called precious metals, gold, platinum, iridium, and to some extent also silver and copper. Excepting these, coal alone presents itself as carbon and hydrogen in an unoxidized condition. But what about the oceans of water, which have occasionally been cited as representing a vast store of heat-producing power ready for our use when coal shall be exhausted. Not many months ago, indeed, on the occasion of a water gas company being formed, statements to this effect could be seen in some of our leading papers. Nothing, however, could be more fallacious. When hydrogen burns, doubtless a great development of heat ensues, but water is already the result of this combustion (which took place upon our globe before the ocean was formed), and the separation of these two substances would take precisely the same amount of heat as was originally produced in their combustion. It will thus be seen that both the solid and fluid constituents of our earth, with the exception of coal, of naphtha (which is a mere modification of coal), and the precious metals, are products of combustion, and therefore the very reverse of fuel. Our earth may indeed be looked upon as " a ball of cinder, rolling unceasingly through space," but happily i company with another celestial body—th sun,—whose glorious beams are the phys cal cause of everything that moves an lives, or that has the power within itself imparting life, or motion on our earth. Th invigorating influence is made perceptib to our senses in the form of heat, but it fair to ask, what is heat, that it should capable of coming to us from the sun, an of being treasured up in our fuel deposi both below and on the surface of th earth?

If this inquiry had been put to me 3 years ago, I should have been much pe plexed. By reference to books on Physic Science, I should have learnt that heat w a subtle fluid which, somehow or other, ha taken up its residence in the fuel, an which, upon ignition of the latter, w sallying forth either to vanish or to abid elsewhere; but I should not have been ab to associate the two ideas of combustion an development of heat by any intelligib principle in nature, or to suggest any pr cess by which it could have been derive from the sun and petrified, or, as the empty phrase ran, rendered latent in the fuel.

It is by the labors of Mayer, Joule, and other modern physicists, that we are enabled to give to heat its true significance.

Heat, according to the "dynamical theory," is neither more nor less than motion amongst the particles of the substance heated, which motion, when once produced, may be changed in its direction and its nature, and thus be converted into mechanical effect, expressible in foot pounds, or horse power. By intensifying this motion among the particles, it is made evident to our visual organ by the emanation of light, which again is neither more nor less than vibratory motion imparted by the ignited substance to the medium separating us from the same. According to this theory, which constitutes one of the most important advances in science of the present century, heat, light, electricity, and chemical action are only different manifestations of "energy of matter," mutually convertible, but as indestructible as matter itself.

Energy exists in two forms, "dynamic"

or "kinatic energy," or force manifesting itself to our senses as weight in motion, as sensible heat, or as an active electrical current; and "potential energy," or force in a dormant condition. In illustration of these two forms of energy, I will take the case of lifting a weight, say one pound one foot high. In lifting this weight kinatic, muscular energy has to be exercised in overcoming the force of gravitation of the earth. The pound weight when supported at the higher level to which it has been raised, represents "potential energy" to the amount of one unit or "foot pound." This potential energy may be utilized, in imparting motion to mechanism, during its descent, whereby a unit amount of "Work" is accomplished. A pound of carbon then, when raised through the space of one foot from the earth, represents, mechanically speaking, a unit quantity of energy, but the same pound of carbon when separated or, so to speak, lifted away from oxygen, to which it has a very powerful attraction, is capable of developing no less than 11,000,000 foot pounds or unit quantities of energy when-ever the bar to their combination, namely, excessive depression of temperature, is removed; in other words, the mechanical energy set free in the combustion of 1 lb. of pure carbon is the same as would be required to raise 11,000,000 * lbs. weight 1 ft. high, or as would sustain the work which we call a horse power during 5 hours 33 min. We thus arrive at once at the utmost limit of work which we can ever hope to accomplish by the combustion of 1 lb. of carbonaceous matter, and we shall presently see how far we are still removed in our practice from this limit of perfection.

The following illustrations will show the convertibility of the different forms of energy. If I let the weight of a hammer descend in rapid succession upon a piece of iron it becomes hot, and on beating a nail

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* In burning 1 lb. of carbon in the presence of free oxygen, carbonic acid is produced and 14,500 units of heat (a unit of heat is 1 lb. of water raised through 1 deg. Fah.) are liberated. Each unit of heat is convertible (as proved by the deductions of Mayer and the actual measurements of Joule) into 774 units of force or mechanical energy; hence 1 lb. of carbon represents really 14,500×774=11,223,000 units of potential energy.

thus vigorously and skilfully for a minute it will be red-hot. In this case the mechanical force developed in the arm (by the expenditure of muscular fibre) is converted into heat. Again, in rapidly compressing the air in a fire syringe, ignition of a piece of tinder is obtained. Again, in passing an electrical current through the platinum wire it is directly converted into heat, which is manifested by ignition of the wire, whereas the thermopile gives an illustration of the conversion of heat into electricity; to which illustrations many others might be added. The heat of combustion being the result of the chemical combination of two substances, does it not follow that oxygen is a combustible as well as the carbonaceous substance which goes by the name of fuel? This is, unquestionably, the case, and if our atmosphere was composed of a carbonaceous gas, we should have to conduct our oxygen through tubes and send it out through burners to supply us with light and heat, as will be seen by the experiment in which I burn a jet of atmospheric air in a transparent globe filled with common lighting gas; but we could not exist under such inverted conditions, and may safely strike out oxygen and analogous substances, such as chlorine, from the list of fuels.

We now approach the second part of our inquiry—

WHENCE IS FUEL DERIVED?

The rays of the sun represent energy in the form of heat and light, which is communicated to our earth through the transparent medium which must necessarily fill the space between us and our great luminary. If these rays fall upon the growing plant, their effect disappears from direct recognition by our senses, inasmuch as the leaf does not become heated as it would if it were made of iron or dead wood, but we find a chemical result accomplished, viz., carbonic acid gas, which has been absorbed by the leaf of the tree from the atmosphere, is there "dissociated," or separated into its elements, carbon and oxygen, the oxygen being returned to the atmosphere, and the carbon retained to form the solid substance of the tree.

The sun thus imparts 11,000,000 units of energy to the tree for the formation of 1 lb. of carbon in the shape of woody fibre, and these 11,000,000 units of energy will be simply resuscitated when the wood is burnt, or again combined with oxygen to form carbonic acid.

Fuel, then, is derived through solar energy acting on the surface of our earth.

But what about the stores of mineral fuel, of coal, which we find within its folds? How did they escape the general combustion which, as we have seen, has consumed all other elementary substances? The answer is a simple one. These deposits of mineral fuel are the results of primeval forests, formed in the manner of to-day, through the agency of solar rays, and covered over with earthy matter in the many inundations and convulsions of the globe's surface, which must have followed the early solidification of its surface. Thus our deposits of coal may be looked upon as the accumulation of potential energy derived directly from the sun in former ages, or as George Stephenson, with a sagacity of mind in advance of the science of his day, answered, when asked what was the ultimate cause of motion of his locomotive engine, "that it went by the bottled-up rays of the sun."

It follows from these considerations that the amount of potential energy available for our use is confined to our deposits of coal, which, as appears from the exhaustive inquiries lately made by the Royal Coal Commission, are still large indeed, but by no means inexhaustible, if we bear in mind that our requirements will be ever on the increase, and that the getting of coal will become from year to year more difficult as we descend to greater depth. To these stores must be reckoned lignite and peat, which, although not coal, are nevertheless the result of solar energy, attributable to a period of the earth's creation subsequent to the formation of the coal beds, but anterior to our own days. These fuels may be made as efficient as coal if properly treated.

In discussing the necessity of using our stores of fuel more economically, I have been met by the observation that we need not be anxious about leaving fuel for our descendants—that the human mind would surely invent some other source of power when coal should be exhausted, and that such a source would probably be discovered in electricity. I heard such a suggestion publicly made only a few weeks back at a meeting of the International Jury at Vienna, and could not refrain from calling attention to the fact that electricity is only another form of energy, that could no more be created by man than heat could, and involved the same recourse to our accumulated stores.

If our stores of coal were to ebb, we should have recourse, no doubt, to the force radiating from the sun from year to year, and from day to day; and it may be as well for us to consider what is the extent of that force, and what are our means of gathering and applying it. We have, then, in the first place the accumulation of solar energy upon our earth's surface by the decomposition of carbonic acid in plants, a source which we know by experience suffices for the human requirements in thinly populated countries, where industry has taken only a slight development. Wherever population accumulates, however, the wood of the forest no longer suffices even for domestic requirements, and mineral fuel has to be transported from great distances.

The sun's rays produce, however, other effects besides vegetation, and amongst these, that of evaporation is the most important as a source of available power. By the solar rays, an amount of heat is imparted to our earth that would evaporate yearly a layer of water 14 ft. deep. A considerable proportion of this heat is actually expended in evaporating sea water, producing steam or vapor, which falls back upon the entire surface of both land and sea in the form of rain. The portion which falls upon the elevated land flows back towards the sea in the form of rivers, and in its descent its weight may be utilized to give motion to machinery. Water power, therefore, is also the result of solar energy, and an elevated lake may indeed be looked upon as fuel, in the sense of its being a weight lifted above the sea level through its prior expansion into steam.

This source of power has also been largely resorted to, and might be utilized to a still greater extent in mountainous countries; but it naturally so happens that the great centres of industry are in the plains, where the means of transport are easy, and the total amount of available water-power in such districts is extremely limited.

Another result of solar energy are the winds, which have been utilized for the production of power. This source of power is, indeed, very great in the aggregate, but its application is attended with very great inconvenience. It is proverbial that there is nothing more uncertain than the wind, and when we were dependent upon windmills for the production of flour, it often happened that whole districts were without that necessary element to our daily existence.

Ships also, relying upon the wind for their propulsion through the sea, are often becalmed for weeks, and so gradually give place to steam-power on account of its greater certainty. It has been suggested of late years to utilize the heat of the sun by the accumulation of its rays into a focus by means of gigantic lenses, and to establish steam-boilers in such foci. This would be a most direct utilization of solar energy, but it is a plan which would hardly recommend itself in this country, where the sun is but rarely seen, and which even in a country like Spain would hardly be productive of useful practical results.

There is one more natural source of energy available for our uses, which is rather cosmical than solar—viz., the tidal wave. This might also be utilized to a very considerable extent in an island country, facing the Atlantic seas, like this, but its utilization on a large scale is connected with great practical difficulty and expenditure, on account of the enormous area of tidal basin that would have to be constructed.

In passing in review these various sources of energy which are still available to us, after we have run through our accumulated capital of potential energy in the shape of coal, it will have struck you that none of them would at all supply the place of our willing and ever-ready slave—the steam-engine; nor would they be applicable to our purposes of locomotion, although means might possibly be invented of storing and carrying potential energy in other forms. But it is not force alone that we require, but heat for smelting our iron and other metals, and the accomplishment of other chemical processes. We also need a large supply for our domestic purposes. It is true that with an abundant supply of mechanical force we could manufacture heat, and thus actually accomplish all our purposes of smelting, cooking, and heating, without the use of any combustible matter; but such conversion would be attended with so much difficulty and expenditure that one cannot conceive human prosperity under such laborious and artificial conditions.

We come now to the question—

HOW SHOULD FUEL BE USED?

I propose to illustrate this by three examples which are typical of the three great branches of consumption:

a. The production of steam power.
b. The domestic hearth.
c. The metallurgical furnace.

Steam Engine Consumption.—I have represented on a diagram two steam cylinders of the same internal dimensions, the one being what is called a high-pressure steam cylinder, provided with the ordinary slide valve for the admission of steam and its subsequent discharge into the atmosphere, and the other so arranged as to use the steam expansively (being provided with the Corliss variable expansion gear) and working in connection with a condenser. I have also shown two diagrams of the steam pressures at each part of the stroke, assuming in both cases the same initial steam pressure of 60 lbs. per square inch above the atmospheric pressure, and the same load upon the engine. They show that in the latter case the same amount of work is accomplished by filling the cylinder, roughly speaking, up to $\frac{1}{3}$ part of the length as in the other by filling it entirely. Here we have then an easy and feasible plan of saving $\frac{2}{3}$ of the fuel used in working an ordinary high-pressure engine, and yet probably the greater number of the engines now actually at work are of the wasteful type. Nor are the indications of theory in this case (or in any other when properly interpreted) disproved by practice; on the contrary, an ordinary non-expansive non-condensing engine requires commonly a consumption of from 10 to 12 lbs. per horse power per hour, whereas a good expansive and condensing engine accomplishes the same amount of work with 2 lbs. of coal per hour, the reason for the still greater economy being, that the cylinder of the good engine is properly protected by means of a steam jacket and lagging against loss by condensation within the working cylinder, and that more care is generally bestowed upon the boiler and the parts of the engine, to insure their proper working condition.

A striking illustration of what can be accomplished in a short space of time was brought to light by the Institute of Mechanical Engineers, over which I have at present the honor to preside. In holding their annual general meeting in Liverpool in

1863, they instituted a careful inquiry into the consumption of coal by the best engines in the Atlantic Steam Service, and the result showed that it fell in no case below 4½ lbs. per indicated horse power per hour. Last year they again assembled with the same object in view, in Liverpool, and Mr. Bramwell produced a table showing that the average consumption by 17 good examples of compound expansive engines did not exceed 2¼ lbs. per indicated horse power per hour. Mr. E. A. Cowper has proved a consumption as low as 1½ lbs. per indicated horse power per hour in a compound marine engine, constructed by him with an intermediate superheating vessel. Nor are we likely to stop long at this point of comparative perfection, for in the early portion of my address I have endeavored to prove that theoretical perfection would only be attained if an indicated horse power were produced with $\frac{1}{5 \cdot 5}$ lb. pure carbon, or say ¼ lb. of ordinary steam coal per hour.

Here then we have two distinct margins to work upon, the one up to the limit of say 2 lbs. of coal per horse power per hour, which has been practically reached in some and may be reached in most cases, and the other up to the theoretical limit of ¼ lb. per horse power per hour; which can never be absolutely reached, but which inventive power may and will enable us to approach!

Domestic Consumption.—The wastefulness of the domestic hearth and kitchen fire is self-evident. Here only the heat radiated from the fire itself is utilized, and the combustion is generally extremely imperfect, because the iron back, and excessive supply of cold air, check combustion before it is half completed. We know that we can heat a room much more economically by means of a German stove, but to this it may be very properly objected that it is cheerless because we do not see the fire or feel its drying effect upon our damp clothing; moreover, it does not provide in a sufficient degree for ventilation, and makes the room feel stuffy. These are, in my opinion, very weighty objections, and economy would not be worth having if it could only be obtained at the expense of health and comfort. But there is at least one grate that combines a increased amount of comfort with reasonable economy, and which, although accessible to all, is as yet very little used. I refer to Captain Galton's "Ventilating Fireplace," of which you observe a diagram upon the wall. This fireplace does not differ in external appearance from an ordinary grate, except that it has a higher brick back, which is perforated at about midheight to admit warmed air into the fire so as to burn a large proportion of the smoke which is usually sent up the chimney unburnt, for no better purpose than to poison the atmosphere which we have to breathe.

The chief novelty and merit of Captain Galton's fireplace consists, however, in providing a chamber at the back of the grate, into which air passes directly from without, becomes moderately heated (to 84 deg. Fah.), and, rising in a separate flue, is injected into the room under the ceiling with a force due to the heated ascending flue. A plenum of pressure is thus established within the room whereby indraughts through doors and windows are avoided, and the air is continually renewed by passing away through the fireplace chimney as usual. Thus the cheerfulness of an open fire, the comfort of a room filled with fresh but moderately warmed air, and great economy of fuel, are happily combined with unquestionable efficiency and simplicity; and yet this grate is little used, although it has been fully described in papers communicated by Captain Galton, and in an elaborate report made by General Morin, le Directeur du Conservatoire des Arts et Metiers of Paris, which has also appeared in the English language.

The slowness with which this unquestionable improvement finds practical application is due, in my opinion, to two circumstances,—the one is, that Captain Galton did not patent his improvement, which makes it nobody's business to force it into use, and the other may be found in the circumstance that houses are, to a great extent, built only to be sold and not to be lived in. A builder thinks it a good speculation to construct a score of houses after a cheap design, in order to sell them, if possible, before completion, and the purchaser immediately puts up the standard bill of "Desirable Residences to Let." You naturally would think that in taking such a house you had only to furnish it to your own mind, and be in the enjoyment of all reasonable creature comfort from the moment you enter the same. This fond hope is destined, however, to cruel disappointment; the first evening you turn on the gas, you find that although the pipes are there, the gas prefers to pass out by the joints into the room instead of by the burners; the water in like manner takes its road through the ceiling, bringing down with it a patch of plaster on to your carpet. But, worst of all, the products of combustion from the firegrates (made probably to dimensions irrespective of the size of the room), stoutly refuse to avail themselves of the chimney flues, preferring to disperse themselves in volumes of smoke into the room. Plumbers and chimney doctors are now put into requisition, pulling up floors, dirtying carpets, and putting up gaunt-looking chimney-pots; the grates themselves have to be altered again and again, until by slow degrees the house becomes habitable in a degree, although you now only become fully aware of the innumerable drawbacks of the arrangements adopted. Nevertheless, the house has been an excellent one "to sell," and the builder adopts the same pattern for another block or two in an increasing neighborhood. Why should this builder adopt Captain Galton's fireplace? It will not cost him much, it is true, and it will save the tenant a great deal in his annual coal bill, not to speak of the comfort it would give him and his family; but nobody demands it of him, it would give him some trouble to arrange his details and subcontracts, which are all settled beforehand, and so he goes on building and selling houses in the usual routine way. Nor will this state of things be altered until the dwellers in houses will take the matter in hand, and absolutely refuse to put up with builders' ways, or, what is still better, get builders who will put up houses in their way. This is done to some extent by building societies, but there is as yet too much of the old leaven left in the trade, and the question itself is too little understood.

Consumption in Smelting Operations.—We now come to the third branch of consumption, the smelting or metallurgical furnace, which consumes about 40,000,000 of the 120,000,000 tons of the coal produced. Here also is great room for improvement; the actual quantity of fuel consumed in heating a ton of iron up to the welding point, or in melting a ton of steel, is more in excess of the theoretical quantity required for these purposes than is the case with regard to the production of steam power and to domestic consumption. Taking the specific heat of iron at .114 and the welding heat at 2,900 deg. Fahrenheit, it would require .114×2,900=331 heat units to heat 1 lb. of iron. A pound of pure carbon develops 14,500 heat units, a pound of common coal say 12,000, and therefore one ton of coal should bring 36 tons of iron up to the welding point. In an ordinary reheating furnace a ton of coal heats only $1\frac{2}{3}$ ton of iron, and therefore produces only $\frac{1}{20}$ part of the maximum theoretical effect. In melting one ton of steel in pots 2½ tons of coke are consumed, and taking the melting point of steel at 3,600 deg. Fahrenheit, the specific heat at .119, it takes .119×3,600= 428 heat units to melt a pound of steel, and taking the heat-producing power of common coke also at 12,000 units, one ton of coke ought to be able to melt 28 tons of steel. The Sheffield pot steel melting furnace therefore only utilizes $\frac{1}{70}$th part of the theoretical heat developed in the combustion. Here therefore is a very wide margin for improvement, to which I have specially devoted my attention for many years, and not without the attainment of useful results. Since the year 1846, or very shortly after the first announcement of the dynamical theory, I have devoted my attention to a realization of some of the economic results which that theory rendered feasible, fixing upon the regenerator as the appliance which, without being capable of reproducing heat when once really consumed, is extremely useful for temporarily storing such heat as cannot be immediately utilized, in order to impart it to the fluid or other substance which is employed in continuation of the operation of heating, or of generating force.

Without troubling you with an account of the gradual progress of these improvements, in which my brother Frederick has taken an important part, I will describe to you shortly the furnace which I now employ for melting steel. It consists of a bed made of very refractory material, such as pure silica, sand and silica or Dinas brick under which 4 regenerators (or chambers filled with checkerwork of brick) are arranged in such a manner, that a current of combustible gas passes upward through one of these regenerators, while a current of air passes upwards through the adjoing regenerator, in order to meet in combustion at the entrance into the furnace chamber. The products of combustion, instead of passing directly to the chimney as in an ordinary furnace, are directed downwards through the two other regenerators on their way towards the chimney, where they part with their heat to the checkerwork in such manner that the highest degree of heat is imparted to the upper layers, and that the gaseous products reach the chimney comparatively cool (about 300 deg. Fah.). After going on in this way for half an hour, the currents are reversed by means of suitable reversing valves, and the cold air and combustible gas now enter the furnace chamber, after having taken up heat from the regenerators in the reverse order in which it was deposited, reaching the furnace therefore nearly at the temperature at which the gases of combustion left the same. A great accumulation of temperature within the regenerators is the result, one pair being heated while the other pair is being cooled; it is easy to conceive that, in this way, heat may be produced within the furnace chamber up to an apparently unlimited degree, and with a minimum amount of chimney draught.

Practically the limit is reached at the point where the materials composing the furnace chamber begin to melt. Whereas a theoretical limit also exists in the fact that combustion ceases at a point which has been laid down by St. Clair Deville at 4,500 deg. Fah., and which has been called by him the point of "dissociation." At this point hydrogen might be mixed with oxygen and yet the two would not combine, showing that combustion really only takes place btween the limits of temperature of about 600 and 4,500 deg. Fah.

To return to the regenerative gas furnace. It is evident that there must be economy where, within ordinary limits, any degree of heat can be obtained, while the products of combustion pass in the chimney only 300 deg. hot. Practically a ton of steel is melted in this furnace with 12 cwt. of small coal consumed in the gas producer, which latter may be placed at any reasonable distance from the furnace, and consists of a brick chamber containing several tons of fuel in a state of slow disintegration. In large works, a considerable number of these gas-producers are connected by tubes or flues with a number of furnaces. Collateral advantages in this system of heating are, that no smoke is produced, and that the works are not encumbered with solid fuel and ashes.

It is a favorite project of mine, which I have not had an opportunity yet of carrying practically into effect, to place these gas producers at the bottom of coal-pits. A gas shaft would have to be provided to conduct the gas to the surface, the lifting of coal would be saved, and the gas in its ascent would accumulate such an amount of forward pressure that it might be conducted for a distance of several miles to the works or places of consumption. This plan, so far from being dangerous, would insure a very perfect ventilation of the mine, and would enable us to utilize those waste deposits of small coal (amounting on the average to 20 per cent.) which are now left unutilized within the pit.

Another plan of the future which has occupied my attention is the supply of towns with heating gas for domestic and manufacturing purposes. In the year 1863 a company was formed, with the concurrence of the Corporation of Birmingham, to provide such a supply in that town at the rate of 6d. per 1,000 cubic ft.; but the Bill necessary for that purpose was thrown out in Committee of the House of Lords because their Lordships thought that if this was as good a plan as it was represented to be, the existing gas companies would be sure to carry it into effect. I need hardly say that the existing companies have not carried it into effect, having been constituted for another object, and that the realization of the plan itself has been indefinitely postponed. It has, however, lately been taken up and partly carried into effect at Berlin.

COAL QUESTION.

Having now passed in review the principal applications of fuel, with a view chiefly to draw the distinction between our actual consumption and the consumption that would result if our most improved practice were made general; and having, moreover, endeavored to prove to you what are the ultimate limits of consumption which are absolutely fixed by theory, but which we shall never be able to realize completely, I will now apply my reasoning to the coal question of the day.

In looking into the "Report of the Select Committee appointed to Inquire into the Causes of the Present Dearness of Coal," we find that in 1872 no less than 123,000,000 tons of coal was got up from the mines of England and Wales, notwithstanding famine prices and the colliers' strikes. In 1862 the total getting of coal amounted to only 83,500,000, showing a yearly average increase of production of 4,000,000 tons. If this progressive increase continues, our production will have reached, 30 years hence, the startling figure of 250,000,000 tons per annum; which would probably result in an increase of price very much in excess of the limits yet reached. In estimating last year's increase of price, which has every appearance of being permanent, at 8s. per ton all round, and after deducting the 13,000,000 tons which were exported abroad, we find that the British consumer had to pay £44,000,000 more than the market value of former years for his supply of coal—a sufficient sum, one would think, to make him look earnestly into the question of "waste of fuel," which, as I have been endeavoring to show, is very great indeed. The Select Committee just quoted sums up its report by the following expression:—"The general conclusion to be drawn from the whole evidence is, that though the production of coal increased in 1872 in a smaller ratio than it had increased in the years immediately preceding, yet if an adequate supply of labor can be obtained, the increase of production will shortly keep pace with that of the last few years."

This is surely a very insufficient conclusion to be arrived at by a Select Parliamentary Committee after a long and expensive inquiry, and the worst of it is, that it stands in direct contradiction with the corrected table given in the same report, which shows that the progressive increase of production has been fully maintained during the last two years, having amounted to 5,826,000 for 1871, and 5,717,000 for 1872; whereas the average increase during the last ten years has only been 4,000,000 tons! It is to be hoped that Parliament will not rest satisfied with such a negative result, but will insist upon knowing whether a proper balance between the demand and supply of coal cannot be re-established, also what can be done to prevent the wholesale conversion of fuel into useless or positively hurtful results.

In taking the 105,000,000 tons of coal consumed in this country last year for our basis, I estimate that, if we could make up our minds to consume our coal in a careful and judicious manner, according to our present lights, we should be able to reduce that consumption by 50,000,000 tons. The realization of such an economy would certainly involve a very considerable expenditure of capital and must be a work of time; but what I contend is, that our progress in effecting economy ought to be accelerated, in order to establish a balance between the present production and the ever-increasing demand for the effects of heat.

In looking through the statistical returns of the progressive increase of population, of steam power employed, and of production of iron and steel, etc., I find that our necessities increase at a rate of not less than 8 per cent. per annum, whereas our coal consumption increases only at the rate of 4 per cent., showing that the balance of 4 per cent. is met by what may be called our "intellectual progress." Now, considering the enormous margin for improvement before us, I contend that we should not be satisfied with this rate of intellectual progress, involving, as it does, an annual deficit of 4,000,000 tons to be met by increased coal production, but that we should bring our intellectual progress up to the rate of our industrial progress, by which means we should make the coal production nearly a constant quantity for several generations to come. By that time our successors may be expected to have effected another great step in advance towards the theoretical limit of effect, which, as we have seen, lays so far above any actual result we have as yet attained, that an annual consumption of 10-000,000 tons would give more than the equivalent of the heat energy which we actually require.

SOLAR HEAT.

I have endeavored to show, in the early part of this lecture, that all available energy upon the earth, excepting the tidal wave, is derived from the sun, and that the amount of heat radiated year by year upon our earth, could be measured by the evaporation of a layer of water 14 ft. deep spread over the entire surface, which again would be represented by the combustion of a layer of coal 8 in. in thickness, covering our entire globe. It must, however, be taken into account that three-fourths of this heat is intercepted by our atmosphere, and only one-fourth reaches the earth itself. The amount of heat radiated away from the sun would be represented by the annual combustion of a thickness of coal 17 miles thick, covering its entire surface, and it has been a source of wonderment with natural philosophers how so prodigious an amount of heat could be given off year after year without any appreciable diminution of the sun's heat having become observable.

Recent researches with the spectroscope, chiefly by Mr. Norman Lockyer, have thrown much light upon this question. It is now clearly made out that the sun consists near the surface, if not throughout its mass, of gaseous elementary bodies, and in a great measure of hydrogen gas, which cannot combine with the oxygen present, owing to an excessive elevation of temperature (due to the original great compression), which has been estimated at from 20,000 deg. to 22,000 deg. Fah. This chemically inert and comparatively dark mass of the sun is surrounded by the photosphere, where its gaseous constituents rush into combustion, owing to reduction of temperature in consequence of their expansion and of radiation of heat into space. This photosphere is surrounded in its turn by the chromosphere, consisting of the products of combustion, which, after being cooled down through loss of heat by radiation, sink back, owing to their acquired density, towards the centre of the sun, where they become again intensely heated through compression, and are "dissociated" or split up again into their elements at the expense of internal solar heat. Great convulsions are thus continually produced upon the solar surface, resulting frequently in explosive actions of extraordinary magnitude, when masses of living fire are projected a thousand miles or more upward, giving rise to the phenomena of sun spots and of the corona which is visible during the total eclipses of the sun. The sun may therefore be looked upon in the light of a gigantic gas-furnace, in which the same materials of combustion are used over and over again.

It would be impossible for me at this late hour to enter further upon speculations regarding the "regeneration of the sun's heat upon its surface," which is a question replete with scientific and also practical interest. We should always remember that nature is our safest teacher, and that in trying to comprehend the great works of our Creator we shall learn how to utilize to the best advantage those stores of potential energy in the shape of fuel which have providentially been placed at our disposal.

THE VALUE OF ARTIFICIAL FUELS
AS
COMPARED WITH COAL.

The question at issue really is, why should artificial fuels be worth considering only during the existence of a coal famine? We are well aware that artificial fuels are in daily use, but I ask to what extent, as compared with the resources we have for producing it. There are thousands of tons annually of really good fuel cast on one side, destroying otherwise profitable land, that, if only dealt with by known processes, would be almost as valuable as the coal itself in its units of work. Rises in the price of coal above the ordinary level are quickly followed by the appearance of this waste in the market, and not till then is it disposed of commercially, after laying for years exposed to the weather during the low or ordinary price of coal; it must be remembered, too, that this residue under consideration, through such exposure, gradually loses in value for heating purposes, and is reduced in bulk through dirt and dust being carried away by wind, partially destroying useful land in the neighborhood, while the slow process of oxidation reduces the percentage of heating power. Thus, if after years of deterioration at the pit's mouth, this stuff is found to be of marketable value, it surely ought not to be allowed to accumulate to the extent it does.

The question is—that, if for the future immediate advantage is taken of this refuse when brought to the pit's mouth, to what extent will it relieve us? Professor Gardner, at the Polytechnic Institution, London, has been telling us lately that there are about 24,000,000 tons of this smudge or waste brought up to the surface annually, but as he has taken a percentage of a rather high total annual get of coal, viz., 140,000,000 tons — whereas it is, I believe, about 120,000,000 tons—we may safely assume that there is not less than 20,000,000 tons of waste brought up with the present annual production of coal.

There is no reason why at any time this *improperly* so termed waste should not be made good use of, let the price of coal come down to what it may; and we must hope that the inertia lately given to the fuel question will start enterprise in the right direction as far as this item is concerned. It may be argued that coal dust is used in the manufacture of patent fuels; but whatever is used in quantity there is an undoubted accumulation of this so-called waste, and this waste, if not allowed to deteriorate by long exposure to the atmosphere, may be made as commercially valuable as the selected class of dust.

For domestic purposes I don't think that patent fuels, in the ordinary sense of the term, are well adapted; but if the 20,000,000 tons just referred to was rightly made use of, it would reduce the existing draw upon coal for steam purposes considerably. I have drawn attention specially to this coal residue question to show that it forms considerable bulk when compared with the staple fuel itself, and, as its cost of get or production equals that of the coal, it is of no minor importance that use should be made of it with the best results attainable, especially when we find the demand for fuel in all directions increasing in the ratio that it is doing.

The question now arises: What is the best way of treating this residue or waste? As it really forms the foundation in bulk of patent fuels as a rule up to the present time, it may and will be assumed that there have been various ways of dealing with it so as to make it a fuel of commercial value. Therefore, for the purpose of illustrating superficially what has been done to attain this object, I have referred back to what has been patented directly for this purpose.

We are supposed to find in the patent records all that is of value, and, of course, plenty that is not of value; and I have taken this course of obtaining what little information I can lay before you this evening for the purpose of connecting the fuel history of the past with the present. To more clearly explain the connection, I have considered it worth while to diagram the mixtures in the relative proportions as set forth in the respective specifications, but only in such cases which I have considered interesting for comparison. In following *them* up we certainly shall find a few extraordinary-looking proportions both in the nature and in the quantities of the several ingredients, but as to the merits of such mixtures or compounds for the purpose required, I will leave the meeting to judge for itself. In searching back through the patent records, the first published specification I can find in connection with fuel is dated April, 1773—exactly one hundred years since. I believe patents for the same subject had been granted long prior to the above date, for I remember some time back noticing in "The Engineer," in one of a series of articles on peat, that a patent was granted to one William Fallowfield, in 1727, "for the use of charred peat in the smelting and manufacture of iron." In the patent of 1773, just referred to, the specification relates chiefly to the purification of coal for smelting purposes, and we may reasonably infer that at this time serious attention began to be paid with respect to fuel, for down to 1792—a period of nineteen years—we find the same John Barber figuring in the patent list, and with the same object.

In the year 1799, which we may call in round numbers nearly three-quarters of a century back, we find the first patent record of a composition or artificial fuel, in which the patentee describes the machinery for separating or screening the coals, taking the small or dust of the same as a base for his fuel, which is to be mixed with any portion or all the ingredients named in the diagrams (1799), in which the various ingredients are simply named, there being no proportion specified. He proceeds to say that they must be mixed together and ground in water in a wooden vessel, after which he moulds the composition into cakes or balls for use. I wish to draw particular attention to this three-quarter of a century old patent, for I think we see there the secret of nearly, if not all, of our patent fuels up to the present day; and it is strange to watch how persistently fresh patents are obtained, almost weekly, for artificial fuels, the component ingredients of which come, in one way or another, within the list before us. The patentee evidently went in for everything and anything that at all stood a chance, and it appears he got exhausted at last when he had to connect "broken glass" *with* "any other combustible ingredient."

In 1800, the year following, we again find a list of ingredients much resembling the former, but it may be noticed that peat is here mentioned, a substance that must have been quite unknown to the former patentee, otherwise he surely would not have omitted such an important ingredient in preference to broken glass. The patentee in this case, too, does not give any definite proportions to his mixture, but specifies that "the proportions of the ingredients vary so as to suit different purposes." The list is given under 1800 to show the resemblance between the two. Twenty-one years later, say fifty years ago, we get a mixture that has, I believe, been used for an artificial or patent fuel to a far greater extent than any other—small coal and tar, in proportion of 3 quarts of the latter to 1 bushel of the former. This is the first patent during the twenty-one years on the immediate subject in question, but I think we may safely assume that during this period artificial fuel must have kept in use more or less, and it seems strange that after such a lapse the patentee of the previous mixture should burst *out with such* a simple modification of his first specification. Perhaps he had run the full term with the patent of 1800, and no doubt in the meantime he had ample experience from actual practice as to value, both in cost and work, of various mixtures and proportions of the ingredients named in his first specification, and at last comes down to the simple coal and tar mixture made into bricks, and for which he secures a fresh patent. The next mention in connection with combined fuel is in 1824, when we get a mixture of one-third to one-fifth of bituminous coal, and the remainder stone coal, or culm, and I think this was simply mixing the one with the other and using it in the ordinary way. In the year following, 1825, we have gas-tar and clay, with sawdust or tanner's bark, or the refuse of dyers' wood, or any species of wood sufficiently granulated or reduced, or turf, or straw, or bran. The patentee gives a proportion of one-fourth gas-tar, one-fourth clay, and two-fourths of any other ingredients, but a proportion that he says burns very bright is one-third tar, one-third clay, and one-third sawdust. The patentee also adds that gas-tar boiled loses much of its smell without materially injuring its quality. He formed his composition into squares or lumps, and exposed them to the weather for a few months.

1826 brings us to a proportion of one-fourth dung, one-fourth sawdust, one-fourth tanner's bark, and one-fourth mud, the above being mixed with sufficient water to bind them well together. Afterwards it is formed into squares, then dried by artificial heat and dipped in hot tar. I really don't think this made a bad fuel, but when we come to such ingredients as tanner's bark, sawdust, and dung, in the large proportions as specified here, we should fail in quantity, whatever kind of a fuel it might make. If we could only introduce a little more of the mud business in our preparation of artificial fuels I'm sure it would be hailed with delight, especially by our corporations.

We now pass over a period of seven years, during which time artificial fuel productions—as far as patents go—lie dormant, but in 1833 we have a specification claiming a mixture of sea coal with brick earth, blue clay, river sand, or deposits of running or stagnant waters. The proportion of coal to be equal to that of either of the other materials, and to be mixed like mortar with tar and made into cakes or balls. The ingredients here contained may be taken from the 1799 list, substituting the river sand for broken glass.

Three years later, or in 1836, we get an extraordinary combination of ingredients, and, from the finite proportions of certain of them, I should imagine that the specification is the result of a long and tedious series of laboratory experiments and tests. The patentee begins with peat, of which he takes one ton in its raw or charred state, and to this he adds 30 lbs. of crude nitre, 14 lbs. of alum (for preventing smoke), 14 lbs. of linseed, 14 lbs. of resin, asphalt, or naphtha, 150 lbs. of coke, 168 lbs. of green vegetable matter and 156 lbs. of animal excrements or other animal matter. For use the mixture is formed into bricks. I cannot say how the peat was dealt with so as to amalgamate properly with these particular substances, but there must have been some means of masticating or triturating it, otherwise perfect mixing would be impossible, as also the formation into bricks.

A year later—1837—we reach the first mention of treating peat alone, as far as concerns operations for the purpose of converting peat, moss, turf, or bog into fuel. It is first cut up or triturated, and then compressed and dried by artificial or other means; hydraulic presses, levers, and screws are mentioned amongst the appliances for compressing.

In the same year we get a well-known name in connection with fuel. C. Wye Williams mixes peat, after mastication, with sand finely powdered, limestone powdered or ground, coal slack, or quick or hot lime. I should in this case expect that the expense of first preparing the peat for mixture, and added to that the cost of grinding or powdering the limestone or sand, would not tell favorably as regards a marketable price in comparison with coal, especially of late years.

About this time the artificial fuel question seems to have received a considerable amount of attention, and in 1838 I find five patents secured for the same. The first of that year illustrates how we still keep to the old ingredients, with perhaps a slight variation in proportions. The patentee in one case adds to one ton of small coal 30 lbs. of tar, 180 lbs. of dry mud, clay, or marl, then mixes with 50 gallons of water, and adds 30 lbs. of lime or chalk. Again, to 10 cwt. of coal dust he adds 5 cwt. of peat, 5 cwt. of sawdust, 200 lbs. of clay or mud, 30 lbs. of lime, and 30 lbs. of tar, the whole being mixed in water and then formed into bricks. Another of the mixtures of the same year is: 7 parts of fullers' earth or strong blue clay, 2 parts of tar, 8 parts of small coal, and 3 parts of mud, the mixture being then formed into bricks for use. I certainly should think this a doubtful fuel, considering there is 50 per cent. of clay and mud to 50 per cent. of small coal with tar in it. Again, in the same year we get 10 per cent. of tar, 18½ per cent. of cinders, peat, or sawdust, 18½ per cent. of clay, sand, or chalk, 50 per cent. of small coal, and 2½ per cent. of acids for another combination. We also in this year again find C. Wye Williams patenting a means of preparing peat, moss, or bog, by pressing it or mixing with it bituminous matter, and we may close the year 1838 with a mixture consisting of 13 cwt. of coke, 4 cwt. of clay or mud, and 1 cwt. of liquid pitch.

In 1839, there is again repeated the "obtaining a fuel by mixing tar or bituminous coal with inferior coal dust;" this is followed up in the same year by Lord Willoughby d'Eresby, patenting the compression of peat in the raw state, and without cutting it up.

In 1840 we find a specification of a mixture to be employed for buildings, mouldings, castings, statuary, imitation of soft or hard rocks, etc., and also to be used as a fuel. Whether any buildings were ever constructed of this fuel or not I am not in a position to say, but I should imagine that the insurance companies would fight shy of them. While upon the subject, I may as well mention as a proof that even now there are people who, with the patentee of thirty years past, believe that for some reason or other it is advisable to construct our dwellings of fuel, for in a specification relating to building materials, dated as recent as last September, I find the following as an abstract: "The said invention relates to a novel treatment of bricks, unburnt clay, soft stone, chalk, plaster of Paris, and other like porous materials, whereby a new material is obtained, which possesses many advantages for building and other purposes. To accomplish this object the inventor takes common bricks, blocks of sandstone, or the other material to be used, and saturates the same with boiled coal tar, melted pitch, or other similar substance."

In the same year, 1840, we find 400 lbs. of tar and 105 lbs. of clay to one ton of small coal, made into bricks, followed up, four months later, by 20 lbs. weight of pitch to 1 cwt. of coal dust, moulded into bricks.

The year 1841 gives us three patents connected with artificial fuels, none of them varying from previous mixtures, with the exception that one of them contains ground *slate.*

In 1842 we find five specifications, the only one worth mentioning, specifying chalk lime, soft stone, bricks, all broken into small pieces and saturated with tar, and then used in the same manner as we use ordinary coal.

In 1843 we again get five patents relating to artificial fuels, one specifying certain proportions of pitch, coal, and coke ground together, and for every ton so ground is added 6 lbs. powdered resin, and 3 gallons of boiled linseed oil; another gives 10 per cent. of pitch or coal tar to 90 per cent. of small coal, and to prevent smoke, there is added 2 to 5 per cent. of common salt dry, or alum dissolved.

In 1844 there are three patents connected with the subject, one of them being "for machinery for getting the moisture out of peat." At this time there seems to have been a fresh impulse given to the fuel question, very probably in the anticipation of locomotive requirements, for in the year 1845 there are seven applications named in artificial fuels, chiefly of the ordinary character, with the exception of one. The specification gives as this mixture: Gutta-percha 3½ parts, coal dust 4 parts, sawdust 2 parts, and coal tar ½ part. Whatever may have been the patentee's idea of the cost of such a fuel at the time, it is pretty conclusive what our own opinion would be now, when we look at the proportion to the whole of such an extraordinary ingredient as gutta-percha and its value. In the same year we find the usual mixture of coal dust with tar, and sometimes added a small portion of chloride of lime, or chloride of soda, or chloride of potash, to take away smell during combustion. We have at the same time "cementing coal dust with Ransome's silicious paste;" perhaps the latter might be used as suggested before, namely, for building materials.

In 1846, although we get six methods of treating fuel, they are of a very ordinary character and the only change is one mentioning the saturation of peat with tar, oil, etc.

In the year following there is a complete dearth as far as fuel patents are concerned, for there is not one registered for that year;

but in 1848 we again get a start with four; but I find that there is still but very little deviation from former mixtures.

For the three years including 1849-50-51, I find nineteen patents recorded in connection with the artificial fuel question, but as a rule, many of them are merely repetitions of what has been enumerated before. One names nothing but tan and resin, which I should imagine might make a very good fire-lighter, although it is not included in that category. The only other worth referring to within the time I have just named is a peculiar treatment of peat, patented in 1850. The following is an abstract of the specification:—"Without previously drying the peat we treat it with waste by a mill in a way similar to that in which chalk is treated in the manufacture of whiting. The resulting liquor is made to pass through a strainer of wire work fine enough to prevent the passage of the large fibres into the tanks or backs cut in the earth, or built upon the surface of the ground if necessary, where it is left to deposit the finer parts of the peat. When this is effected the supernatant liquor is run off from the deposit, and the magma taken out from the tanks or backs and dried either by the air or sun, or on arches of bricks or other absorbent material heated by flues underneath."

In 1852, out of seven specifications relating to artificial fuels, I find one for dissolving peat in a chemical bath and then letting it dry; and another specifying one-twelfth of caustic lime, and one-twelfth of peat charcoal added to ten-twelfths of cut peat, mixed into a cement and moulded.

For the year 1853 I have selected two, out of a total of nine applications during that year. The first I give on the ground of its peculiarity, being composed of one-third of sea mud to two-thirds of sea-weed, and to 2,000 lbs. of this mixture is added 4 lbs. of nitrate of lead. Whether such ingredients would or would not make a decent fuel I am unable to say. The second specification for the same year shows how the same ingredients, that are now old to us, are still being used and in what proportions; but the patentee in this latter case goes in for moulding his mixture in various forms, and altogether departs from the usual antiquated brick form. During the same year we meet again with the small coal and tar business in the brick form, and in the specification I find a description of drying peat by heated revolving cylinders; while yet in another we have the treating of peat chemically while in the pugmill.

Out of a number of eight patents in 1854 for fuel there is not one of interest apart from what has already been shown, with the exception of one I may mention that is solely for the form or shape of any mixed or artificial fuel, the configuration being various, and having holes or passages through them for the purpose of better combustion.

In 1855 we number six patents.

A mixture for 1856 well shows the extremes that are adopted by different patentees in proportioning the ingredients: take here the enormus bulk of clay, 83 parts to coal 15 parts—to me rather an extraordinary proportion; if it was not we should I think have heard more of it than what I am telling you now. There are nine patents for this year, but the one referred to is the only one worth notice, and that on account of its peculiarity.

During the year 1857 there is not anything worth mentioning, and in 1858 we get rye-flour as an ingredient. We again have ground peat mixed with tar.

In the year 1860 the number of patents fell to four, and the only one I shall notice gives equal portions of human or animal excrement, sawdust or chips, and small coal, and to this mixture add one-sixth part clay.

The most novel from the 1861 patents, of which there are five, relates to making boxes of wood about the size of a brick, then filling them with coal dust, and afterwards closing them up; in fact, it is enclosing a brick of coal in a wooden case, and then using it for fuel—a rather expensive method I should think of using timber as an ingredient.

In 1862 there are four patents for artificial fuel, but not anything of unusual interest.

The year following we again hear of seaweed treatment for fuel purposes. In one specification I find lime saturated with tar, which, after being used as a fuel, will, when ground, make a good cement, certainly a profitable way of dealing with the residue, especially if there is any real good in the fuel portion of the method. These two, out of five patents for 1863, are the only ones worth attention, with the exception that the last named process was duplicated by a subsequent patent a few months afterwards.

In 1864 we reach up to nine patents in connection with the subject, and one is peculiar in its ingredients. The patentee seems rather doubtful as to the proper relative proportions, for he names peroxide of manganese, 1 lb. to 10 lbs.; sulphate of lime, 5 to 50 per cent.; coal or coke, 100 lbs.; rosin and asphalt, 2 per cent.; oils, 7 to 12 per cent.; rosin or pitch, 12 to 20 per cent. In the remaining patents we have 90 parts of coal to 10 parts of cow dung twice over; we get also equal portions of peat and charcoal pressed together. The only other worth mentioning specifies cutting peat into blocks, putting them into an air-tight receiver, exhausting the air and moisture, and then admitting petroleum or any like substance.

I have placed one of the three 1865 patents among those worth notice as a novel composition; we have been in want of one lately, and I think this supplies the gap. We get 20 lbs. of meal to 3½ lbs. of pitch or tar, and 2½ lbs. of alum. It might make a very good fuel, but I am in doubt as to both supply and cost of the chief ingredients. One of the remaining patents treats only of the configuration of any fuel.

In the next year the number of patents doubles, but there are not any of interest with the exception of one I may mention, which gives to 1 ton of coal, 2 cwt. of sawdust, 40 gallons of tar, and 2½ cwt. of salt.

The year 1867 reaches ten patents on the subject, and all of them of what I may term the ordinary type. One is simply the coal and tar brick with holes pierced through as in 1864; another combines resin, glue, and salt with coal dust at a proportion of 50 lbs. of the mixture to the ton of coal.

In 1868 we again get ten patents on the same question, and I have selected two for the purpose of noticing the difference between the simple and the compound. In the first case we have 8 per cent. of coal tar to one ton of coal moulded into bricks. I suppose it is due to the simplicity of the idea of glueing small coal together with tar that we find it so often mentioned, but I wonder if the patentees could be aware of the age of the mixture at the time of securing their patents, when no doubt it was as common an article in fuel commerce as it ever has been. The second case gives very careful proportions of delicate ingredients, for, it is stated, to 17½ cwt. of coal dust and 2½ cwt. of clay, must be added 5 lbs. of rice, 5 lbs. of Indian meal, 5 lbs. of resin, and 20 lbs. of asphalt. I believe the smaller portions are admitted to gain the object of combustion with less smoke than ordinary fuel. In the same year we have two patents with the same ingredients and proportions as nearly corresponding as possible, viz., to

1 ton of duff add 2 cwt. of pitch and 2 cwt. of salt, and in the same year we again find turf saturated with oils or other like substances.

During 1869 out of six patents I may mention two of precisely the same treatment, viz., about 8 per cent. of rosin to coal, and another where carbolic acid is introduced in the proportion of 5 gallons to 1 ton of coal, together with 56 lbs. of pitch and 8 lbs. of salt.

In 1870 seven patents are recorded; as the date is nearing the present, I have taken three for the sake of comparison with former years. In the first we get the 10 per cent. of pitch, to 90 per cent. of coal and some sea weed, the proportion of which is not stated. The second is a compound of silicate of soda, salt, lime, and sulphuric acid, to 15 per cent. of which mixture coal is added. The third patent is certainly not novel, but suffices to trace the likness as we go on. We also hear in that year, of human excrement mixed with charcoal, of chalk with charcoal and pitch, and another arrangement of taking small coal and grinding it to a powder, and then mixing it with pitch or tar. We must bear in mind this is the year 1870; what the patentee's idea could have been respecting the cost of a fuel that required coal to be ground to powder, at a time when coal itself was at its lowest, seems strange; but even at the panic prices such a fuel could not, I think, have competed with coal; moreover, I cannot understand why the coal dust should be ground at all, let alone "to a powder."

We lower to five patents in the following year (1871), but I take two illustrations to show, in the one case the costly production, and in the other our old friend up again associated with a little food. As regards the first, to take 25 per cent. of creosote oil to 68 per cent. of coke, and add 5 per cent. of bituminous coal, and 2 per cent. of lime, cannot pay commercially, or compete with ordinary fuel. In the second we get our usual 1 ton of coal, to which is added 100 lbs. of pitch and 10 lbs. of farina, an ingredient we have met with before under another designation. I may remark before closing up this year of 1871, that we have mentioned in a specification a mixture of blood and lime with small coal.

For last year, 1872, I find nine patents recorded, and again of the stereotyped combinations. One patent 12 months ago is nearly similar to the patent of 1821. From this we may judge what progress has been made in the last 52 years, as regards artificial fuels of this particular class, and remember, of a class that has been found the most economical in production; possibly, too, the most efficient for the purpose for which it is required. It is needless to give farther trouble with abstracts of specifications; sufficient, I think, has been shown to illustrate a doubtful progress in the artificial fuel questions, and although we have had, subsequent to the last patent, and continue to have, applications for patents for artificial fuels, especially of late, there is not any thing new in them. Really some of the latest specifications read almost as copies of I may say, dozens that have appeared before.

In taking a retrospect of the various means of compounding an artificial fuel, the question arises, what material have we in quantity that is available for heat-producing purposes to anything like the extent required for relieving the draw upon the coal itself. I think we may assume that the coal residue is disposed of, or will be in the future, in a satisfactory manner, without those mixtures that appear on the diagrams more like "household receipts" than an article of consumption demanded in millions of tons annually. We have had in consideration sawdust, tanner's bark, asphalt, resin, and almost everything that will burn at all; but whatever use the whole or any part of these constituents, by addition, may serve towards making a good heat-producing fuel, it will be admitted that, for general purposes, even taking domestic consumption alone, the quantity collectively at command is anything but equal to the demand; and taking it for granted that certain admixtures will, laboratorily, give certain results in percentage of heat or work, it must be remembered that the requirement is a very great and a national one, and consequently any substitute for coal that may be introduced must be simple and not compound.

Combinations must naturally be expensive, if only from a mechanical point of view, whatever may be the value of the ingredients, even supposing we had quality; but while there is a query respecting quantity, coupled with the cost of quality, I think we can only arrive at the one conclusion, viz., take the most quantitative substitute, and at the same time the most simple, and see of what value it is, and how it can be dealt with to perfect it sufficiently to form a relief to coal.

The next, as compared with coal in quantity (putting quality on one side at present), is "Peat," the half-brother to coal. For the sake of comparison, I will take the relative areas of coal and peat as generally estimated for Great Britain, viz., coal about 7,750,000 acres, and peat about 6,000,000 acres, and taking peat as averaging double the thickness of coal over the estimated area, we get 12,000,000 acres of peat as compared with 7,750,000 acres of coal of the same thickness as peat; this is in bulk. Again, take peat in its condensed form as equalling one-fifth of its average original bulk, we then get 2,500,000 acres of peat equal in density to coal, or say, one-third. It must be borne in mind, however, that coal has been worked to an extent quite different to peat, consequently we may infer that the present actual relative proportions between the two must be much more in favor of peat than these figures represent.

In passing, it will be as well to notice here why the question of manufacturing peat into a marketable fuel is of, I consider, great importance in more respects than one. In the first place it has the unequivocal advantage of being procurable upon the surface of the ground; and whatever may have been the difficulties heretofore, or even at present, as regards drainage, cutting, and general treatment of peat, it must be admitted that this one desideratum is strongly to be encouraged. Morally speaking, it is advisable to dwindle down as much as possible the extent of the almost inhuman labor below the surface compulsory for the production of coal—and labor that very few of those uninitiated could by any stretch of imagination anticipate, even excluding the risks that are in constant attendance upon such labor—and also take into consideration the últimate result of the process upon the human intellect, as exemplified only too visibly of late, a result which gave rise at the moment to the controversy of how to economize an article of consumption that necessitated such uncivilized labor for its production. Of course, we know that the whole of this undesirable labor cannot be dispensed with at once, but we must confess that it is desirable to aim at such a purpose, and, by the utilization of peat and the introduction of coal-cutting machines below, we may soon anticipate a reduction in the extent of underground work.

Respecting the calorific power of peat, as compared with coal, I think we may safely assume that it reaches, in efficiently worked and well dried peat, an average of 75 per cent.; naturally the percentage varies considerably with different qualities of peat, some results being much higher and others much lower, but I think the above to be a *fair* average.

We next come to the question, "Why has peat been so little known generally as a valuable fuel, although staring us in the face by thousands upon thousands of acres in various parts of the country?" The answer is, that peat in its natural or raw state contains, according to the depth from surface and nature of deposit, a very great percentage of water, and it has been the disposing of this water that has proved the real difficulty in the way of producing peat as a fuel to at all compete with coal.

In referring back to the year 1800 we find peat mentioned in the list, but it is only stated as one of the ingredients of the mixture, and it does not specify how it is proposed to treat it so as to make it available for mixing; but in 1837 we have mention of "Operations for the purpose of converting peat moss and peat turf or bog into fuel." It is stated to be first cut up and then compressed and dried by artificial or other heats; and there are several methods named respecting the compression, such as hydraulic presses, levers, and screws.

We all know that for many years past machinery has been in operation for converting peat into a commercial or marketable fuel, and there are hundreds of tons of it being used; but still the question is, why only in hundreds of tons, when it ought to be, I may say, hundreds of thousands of tons? The answer is, as I said before, that the expenses incurred in trying to get rid of the water to an extent that will bring the specific gravity of the peat to something approaching that of coal, are so great, that it has been impossible to place it before the public in competition with coal in a commercial point of view, at the low prices coal has been standing at for years, until lately; and it is only in such cases as the late crisis that latent energy is wakened up for the purpose of seeing what can be done. I maintain that, let the price of coal come down to its own standard, or even lower, we must not lose the patent fuel question out of sight now that necessity has compelled us to grapple with it. We know how easily circumstances are allowed to fall into their normal state after an excitement is over; but this is a question of national importance, and now that it is proved that peat can be treated in a manner that will almost bring it down weight for weight in equal bulk with coal, and that it can be brought into the market at a much less cost than coal at its cheapest, I trust that we shall soon have it as common an "household word" as coal, especially for domestic use. At the Dartmoor prison peat has for a long time performed every function required of coal; it warms the whole place and is also converted into gas for their own consumption, and all this is done with peat in a much more imperfect state than it can now be produced.

It may perhaps be interesting here to glance at the methods employed in treating peat, and the results obtained. I will again revert to its remarkable power of retaining water; when simply dried in the air, without any preparation, it will only part with about 70 per cent. of its moisture, no matter how long the exposure. If moderately cut up, or macerated, and then pressed and air-dried, it will still keep back about 20 per cent., and it must be borne in mind that the more the moisture retained, the less the calorific power of the peat; consequently, the drier the peat can be produced the greater the heating power. The great desideratum, therefore, is to get rid of the whole of the moisture, and if not all, as much of it as we possibly can. Artificial means of drying after compression have often been tried, but, even supposing that such a process resulted in a production as perfect as could be wished, the very fact of having to consume fuel to obtain the result, upsets all economical views of the case and thereby makes it too expensive for competition with coal.

To get peat to be universally adopted it is imperative that in the first place it must be freed from the whole of the moisture, or next door to it, for in a perfect condensed state it will give its greatest value in units of heat and take up the least stowage, which is very often a consideration; in the second place, it must be produced at a much less cost than ever coal can come to, otherwise it will never be of commercial value.

To gain these points there is only one way of getting at it, viz., thorough mastication or trituration of the raw material. I emphasize the word "thorough" for the reason that if the fibrous rooty portions of the peat are not cut up minutely, so as to release the water and air previously held fast by capillary attraction, you will never get rid of the moisture. Then after thorough mastication, simple exposure to the atmosphere for drying, and not artificial means. From the controversy on this question some time ago, it appears that this approach to perfection, if we may so call it, has only lately been accomplished by Clayton's machinery, which in my own judgment seems in design to be undoubtedly the best yet adapted for the special purpose, and certainly from the results obtained I think we may now hope speedily to see the thousands of acres of bog, now so much waste land, being made use of to an universal benefit.

The machinery in question accomplishes what has long been aimed at, not only in the mechanical treatment of the material, but I believe in cost of production as well; but as it is not the purport of this paper to subscribe or advocate any particular machinery or process for manufacturing either peat or other fuel, sufficient will have been said on that point.

The real object of this paper has been to glance rapidly through the past history of artificial fuels for the purpose of comparing with the present enthusiastic attempts that are being weekly brought to public notice through the patent lists as new, and to note what advance has been made; but if you take the trouble to peruse some of the latest, and very latest, specifications—and some of them are not very long—and then turn to the diagram list of 1799, you will find the same ingredients anticipated, although proportions may vary, which has been the case, more or less, ever since that date. I think, therefore, you will agree with me that as far as compound artificial fuels are concerned there has been no real advance, for to compare at all with coal it must be simple and in quantity.

The only advance of real good, seems to

be the stride lately made in the manufacture of peat; and if the quality and marketable price only turns out what is promised, and I do not see any reason to doubt the good faith of it, I think we may congratulate ourselves and the community at large in having the question at last solved, of being able to procure a fuel in quantity and of a quality combining cleanliness in its purchasable form, together with a bright fire, less smoke, and still less residue during combustion.

In conclusion I will reiterate the hope that the time is not far distant when we shall see vast tracts of what is at present so much waste and useless country swarming with industry on the surface, which both physically and morally will be something towards alleviating the wretched labor at present required below the surface.

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